Immediate Loading of Splinted Locking-Taper Implants: 1-Year Survival Estimates and Risk Factors for Failure

Mohammed S. Erakat, BS[1]/Sung-Kiang Chuang, DMD, MD[2]/Roy H. Yoo, DMD[3]/
Meghan Weed, BS[4]/Thomas B. Dodson, DMD, MPH[5]

Purpose: *The purpose of this study was to estimate the 1-year survival rate of immediate vertical-load splinted locking-taper implants and to identify risk factors for implant failure.* ***Materials and Methods:*** *To address the research aim, the investigators implemented a retrospective cohort study design and enrolled a sample derived from the population of patients who had received immediate vertical-load splinted implants (Bicon, Boston, MA). The predictor variables were the sets of exposures associated with implant failure and classified as demographic, health status, anatomic, implant specific, prosthetic, and surgical. The primary outcome variable was implant failure, which was defined as implant removal. Descriptive, univariate, and multivariate analyses using clustered marginal approach of the Cox proportional hazards models were computed. The level of statistical significance was set at* $P < .05$. ***Results:*** *The study cohort was composed of 209 patients who received 477 implants. The overall 1-year Kaplan-Meier survival estimate was 90.3% (95% CI: 86.9%, 93.7%). In the multivariate model, implant placement in a delayed manner versus implantation the same day as extraction (hazard ratio = 3.7,* $P = .002$*), uncoated implants versus coated implants (hazard ratio = 22.1,* $P < .001$*), and an increased per-unit number of pontics involved in the temporary prosthesis (hazard ratio = 1.8,* $P < .001$*) were statistically associated with an increased risk of implant failure.* ***Conclusions:*** *An overall 1-year survival estimate of 90.3% (95% CI: 86.9%, 93.7%) was calculated for immediately loaded splinted implants. After controlling for other variables, 3 variables—timing of implant placement relative to extraction (delayed implant placement after tooth extraction), coating of implant (uncoated), and increased number of pontics—were associated with an increased risk for implant failure.* Int J Oral Maxillofac Implants 2008;23:105–110

Key words: *dental implants, immediate loading, multivariate models, retrospective cohort study, risk factors*

[1]Resident-in-Training, University of Medicine and Dentistry of New Jersey (UMDNJ), Department of Oral and Maxillofacial Surgery, Newark, New Jersey.
[2]Assistant Professor, Department of Oral and Maxillofacial Surgery, Harvard School of Dental Medicine, Boston, Massachusetts; Department of Oral and Maxillofacial Surgery, Massachusetts General Hospital, Boston, Massachusetts.
[3]Private Practice, Garden Grove, California.
[4]Dental Hygienist and Research Coordinator, Implant Dentistry Centre, Boston, Massachusetts.
[5]Associate Professor, Department of Oral and Maxillofacial Surgery, Harvard School of Dental Medicine; Director, The Center for Applied Clinical Investigation, Department of Oral and Maxillofacial Surgery, Massachusetts General Hospital, Boston, Massachusetts.

Correspondence to: Dr Sung-Kiang Chuang, Massachusetts General Hospital, Department of Oral and Maxillofacial Surgery, 55 Fruit Street - Warren 1201, Boston, MA 02114. Fax: +617 726 2814. E-mail: schuang@hsph.harvard.edu

For more than 20 years, the standard protocol for placing dental implants has been a 2-stage approach. During the first stage, the implant is inserted and permitted to heal without loading for 3 to 6 months. During the second stage, the implant is exposed and then loaded with a prosthesis.[1,2] The load-free healing period was proposed to be a critical element for implant integration.[3] The rationale for the delay between implant placement and loading was that osseointegration must take place before the implant is loaded to minimize the risk of failure.[4,5]

Some patients object to remaining edentulous during this prolonged treatment course.[4] To address this patient-initiated demand for shorter treatment, clinicians have initiated innovative treatment protocols, including loading implants 0 to 3 days after placement.[4] When full occlusal load is placed on the implant through a provisional or definitive prosthesis within 72 hours after placement, the implant is considered imme-

Fig 1 The integrated abutment crown (IAC) and implant of the Bicon implant system (Bicon, Boston, MA).

diately loaded.[6] Immediate loading of implants shortens treatment time and also provides patients with an acceptable esthetic appearance during the treatment period.[7] There is concern, however, that this protocol may result in an increased frequency of implant failure.[8]

The purpose of this study was to evaluate clinical outcomes of immediately loaded implants. The hypothesis of this study was that 1 or more risk factors that exist that can be modified by the clinician to decrease the probability of implant failure. The specific aims of this study were to estimate the 1-year survival rate of immediately loaded implants and to identify risk factors for implant failure.

MATERIALS AND METHODS

Study Design and Sample

The investigators applied a retrospective cohort study design to address the specific aims of the study. The sample was derived from a population of patients who had been treated with Bicon implants (Bicon, Boston, MA) placed by practitioners at the Implant Dentistry Centre at Faulkner Hospital (IDC-FH), Boston, Massachusetts, between July 2001 and July 2003. A total of 1,331 implants were placed in 646 patients during this period. All subjects who had had implants placed and immediately loaded were eligible for inclusion in the study. Immediately loaded implants were defined as locking-taper implants that had been restored with a functional, vertically loaded, fixed provisional prosthesis placed on the implant and stabilized by splinting to adjacent teeth or fixed restorations within 24 hours of implant placement. In the overwhelming majority of cases, the provisional restoration was placed on the same day as implant insertion. Patients who did not have primary stability at the time of implant placement or who did not have any available adjacent structures for bonding of the provisional restoration could not be treated with the immediate stabilization and function technique.

Study Variables

The predictor variables were grouped into the following categories:

1. Demographic variables: These variables included the patient's age at time of implant placement (years) and gender.
2. Health-status variables: Current tobacco use status and whether the patient had a medical condition that could affect wound healing (eg, diabetes, chronic steroid use, or radiation therapy to the head and neck) were recorded.
3. Anatomic variables: The anatomic variables included implant location (maxilla, mandible, anterior, posterior), dentition status (partially edentulous or full-arch edentulism), bone quality (types 1 to 4), and implant relationship to other teeth or implants. Bone quality was determined at the time of implant placement. The amount and appearance of bone in the flutes of the 3.5-mm reamer were evaluated following withdrawal of the reamer from the osteotomy.[9,10] Type 1 classification was used for cortical bone that was compact and nearly bloodless. Type 2 classification was used if the flutes were filled with red bone. Type 3 was used for intermediate findings. Type 4 was used if there was no bone in the flutes. Implant relationship to other dentoalveolar structures was grouped into the following categories: number of implants, number of root canal–treated teeth, number of teeth with periapical radiolucencies adjacent to the implant, and whether the implant site was previously root canal–treated.
4. Implant-specific variables: These variables included implant size (width, length), implant coating (uncoated, titanium plasma-sprayed [TPS], or hydroxyapatite [HA]), and size of the implant well (Fig 1).
5. Prosthetic variables: The main prosthetic variable was the total number of units in the prosthesis, defined as the sum of implants, natural teeth, and pontics making up the temporary prosthesis. This variable was subdivided into 3 categories: the total number of natural teeth, the total number of pontic units, and the total number of implants participating in the temporary prosthesis.
6. Surgical variables: These variables included treatments used to reconstruct the implant recipient site (eg, internal or lateral sinus lifts), barrier membranes, autologous or allogeneic bone grafts, and timing of implant placement relative to the tooth extraction (ie, immediate or delayed).
7. Survival analysis: The following information from each chart was recorded: date of implant placement, dates of follow-up visits, and date of implant removal if applicable.

Outcome Variables

Implant failure, defined as removal of the implant, was the primary outcome variable. The time between implant placement and the date of the last follow-up or implant removal was used to calculate the duration of implant survival in months.

Treatment Protocol

The clinical treatment protocol required that the prosthesis be stabilized by bonding to adjacent teeth or to other implants during the osseointegration period. All lateral contacts were eliminated to prevent breakage of the bonding to adjacent teeth or implants. The following is a summary of steps in the treatment protocol.

1. The tooth is extracted or the osteotomy is prepared in a conventional manner.
2. The adjacent teeth or crowns are etched for bonding.
3. The implant is inserted so that it is at least 5.0 mm below the buccal soft tissue.
4. An appropriate abutment of an appropriate width is chosen.
5. A transitional prosthesis is fabricated and placed onto the abutment to confirm fit and occlusion.
6. The transitional prosthesis is bonded to adjacent teeth in a secure manner to stabilize the transitional prosthesis.
7. The transitional prosthesis may be removed after a minimum of 10 weeks of healing, and the implants may be restored in the intended manner.[11]

Statistical Analysis

Microsoft Excel (Microsoft, Redmond, WA) was used to create the database. SAS (SAS Institute, Carey, NC) statistical software was used for data and statistical analysis. Descriptive statistics were computed for all study variables. Nonparametric Kaplan-Meier survival analyses were used to predict the overall 1-year survival rate with associated 95% confidence intervals. Covariates associated with survival were identified using Cox proportional hazards marginal regression analyses based on the semiparametric methodology adjusted for clustered, correlated observations. Univariate analyses with covariates with P values ≤0.15 and biologically important variables (ie, age and sex) were considered candidate variables for inclusion in the multivariate Cox model for evaluation of statistical significance ($P \leq .05$). The Cox proportional hazard modeling approach controlled for confounding features that might affect the outcomes simultaneously (eg, uncoated implant in a female with a site lacking primary stability).

RESULTS

During the study interval, July 2001 to July 2003, 209 subjects received a total of 477 immediately loaded implants. The mean duration of clinical follow-up time was 9.2 months ± 6.0 months (range, 0.0 to 25.3 months). The descriptive statistics are summarized in Table 1. The mean age of the sample was 54.4 ± 15.8 years (range, 15 to 91 years). Nearly half (48.8%) of the patients were male, and 8.7% reported tobacco use. Most of the implants were placed in the maxilla (75.7%) and in an anterior position (53.0%). Fifty percent of the implants were placed immediately after tooth extraction. The majority of the implants placed (98.5%) were coated with either HA or TPS. The overall 1-year Kaplan-Meier survival estimate was 90.3% (95% confidence interval [CI], 86.9% to 93.7%; standard error [SE], 1.7).

The Cox univariate associations between the study variables and implant failure are summarized in Table 2. Four variables were statistically associated with implant failure: age ($P = .04$), coating ($P = .002$), total pontic units ($P < .001$), and condition of implant site (healed extraction site; $P = .02$). These variables were considered candidate variables for inclusion in the multivariate model.

To create the multivariate model, a set of variables were selected that were biologically important (age and sex) or were statistically or near statistically associated with implant failure (ie, $P \leq .15$). In the multivariate model, coating, total pontic units, and condition of the implant site (healed extraction site) remained statistically associated with implant failure (Table 3). The adjusted hazard ratio for coating was 22.1 (95% CI: 6.6 to 74.6; $P < .001$). This hazard ratio is interpreted as meaning that implants that were not coated have 22.1-fold increased risk of implant failure when compared to coated implants. The adjusted hazard ratio for total pontic units was 1.8 (95% CI: 1.3 to 2.5, $P < .001$). This hazard ratio is interpreted as meaning that for each pontic added to the temporary restoration, the risk of implant failure increases approximately 1.8-fold. The adjusted hazard ratio for condition of implant site was 3.7 (95% CI: 1.6 to 8.3, $P = .002$). This hazard ratio is interpreted as meaning that implants placed in a delayed manner after tooth extraction had a 3.7 times increased risk of failure compared to implants placed and loaded immediately following tooth extraction.

DISCUSSION

The 2-stage protocol for placing implants has been used for more than 20 years with very good long-term results.[1,2] Patients, however, have sometimes found

Table 1 Descriptive Statistics

Variable	N	%
Demographic		
Mean age (n = 209)	54.5*	
Sex (n = 209)		
Male	102	48.8
Health status		
Tobacco users (n = 208)	18	8.7
Anatomic		
Anterior	253	53.0
Maxilla	361	75.7
Anterior	197	41.3
Posterior	161	33.8
Mandible		
Anterior	58	12.1
Posterior	61	12.8
Dentition status (k = 477)		
Partially edentulous	407	85.3
Completely edentulous	70	14.7
Bone quality (n = 176)		
Type 1	7	4.3
Type 2	16	9.8
Type 3	56	34.1
Type 3–4	4	2.4
Type 4	81	49.4
Root canal–treated teeth at implant site (k = 337)		
No	199	59.1
Yes	138	40.9
Implant site adjacent to root canal–treated teeth (k = 477)		
None	363	76.1
1	96	20.1
2	18	3.8
Radiolucency at or adjacent to implant site (k = 477)		
None	403	84.5
Implant site	31	6.5
Adjacent tooth	28	5.9
Implant site and adjacent tooth	15	3.1
Implant-specific		
Implant diameter (k = 477)		
3.5 mm	55	11.5
4.0 mm	40	8.4
4.5 mm	185	38.8
5.0 mm	166	34.8
6.0 mm	31	6.5
Implant length (k = 477)		
6 mm	11	2.3
8 mm	327	68.6
11 mm	139	29.1
Implant coating (k = 476)		
Uncoated (grit-blasted acid-etched)	7	1.5
TPS	28	5.9
HA	441	92.6
Implant well size (k = 477)		
2 mm	95	19.9
3 mm	382	80.1
Prosthetic		
Total no. of units (k = 476)		
2	2	0.4
3	138	29.0
4	81	17.0
5	44	9.2
6	84	17.7
7 to 14	127	26.7
Total no. of natural teeth (k = 476)		
0	105	22.0
1	66	13.9
2	302	63.5
3	3	0.6
Total no. of pontics (k = 476)		
0	391	82.1
1	35	7.4
2	14	2.9
3	29	6.1
4	3	0.6
5	4	0.8
Total no. of implants (k = 476)		
1	128	26.9
2	87	18.3
3	68	14.3
4	66	13.8
5 to 14	127	26.7
Dentoalveolar reconstruction procedure at implant site (k = 477)		
Yes	43	9.0
Condition of implant site at time of placement (k = 477)		
Edentulous	238	49.9
Tooth extracted, implant immediately placed	231	48.4
Implant removed, replacement implant placed	8	1.7

*Mean age shown in years (SD, 15.8 years; range, 15 to 91 years).

the healing period uncomfortable, inconvenient, and excessive.[12] Patient demand has resulted in studies encouraging shortened healing periods and immediately loaded implants.[3] The purposes of this study were *(1)* to estimate the 1-year survival of immediately loaded Bicon dental implants and *(2)* to identify risk factors associated with immediately loaded implants.

The results of this analysis suggest that the overall 1-year survival of the immediate-loaded implant system was 90.3%, with an associated 95% CI of 86.9% to 93.7%. These survival results are lower than the mean survival for other studies; 1-year survival rates of 97.1% to 100% have been reported for immediately loaded implants.[3,13,14] This study's larger sample size, when compared to other studies, may reflect a broader, more general clinical experience, thus producing a more accurate estimate of survival outcomes. The previously reported survival rates may be overly optimistic due to insufficient sample size or duration of follow-up. Additionally, survival estimates computed in a binary manner (ie, implant present at the end of follow-up) tend to overestimate survival compared to survival estimates computed using the more appropriate Kaplan-Meier method. Also, survival statistics computed without adjusting for clustered, correlated observations also tend to overestimate survival rates.[15,16] Although there are some benefits

Table 2 Univariate Analysis of Factors (Exposures) Associated with Implant Failure (n = 209 subjects, k = 477 implants)

Exposures	Hazard ratio estimate	95% CI		*P*
Demographic variables				
Mean age (n = 209)	1.03	1.0	1.1	.04
Gender (female) (n = 209)	1.2	0.6	2.3	.68
Health-status variables				
Tobacco use (n = 208)	1.1	0.4	3.0	.92
Anatomic variables				
Jaw (mandible) (k = 477)	0.6	0.3	1.6	.29
Location (posterior) (k = 477)	1.4	0.7	2.9	.31
Dentition status (k = 477)	0.5	0.1	2.1	.34
Bone quality (n = 164)	0.8	0.4	1.4	.37
RCT tooth at implant site (k = 337)	0.6	0.2	1.5	.22
Implant site adjacent to RCT tooth (k = 477)	0.8	0.3	2.0	.70
Radiolucency at or adjacent to implant site (k = 477)	1.0	0.3	2.9	> .99
Implant-specific variables				
Diameter (k = 477)	0.9	0.5	1.7	.80
Length (k = 477)	1.0	0.8	1.3	> .99
Coating (k = 476)	6.8	2.1	22.6	.002
Well size (k = 477)	0.96	0.4	2.2	.92
Prosthetic variables				
Total unit (k = 476)	1.1	0.9	1.3	.27
Total natural tooth (k = 476)	0.8	0.5	1.1	.18
Total pontic units (k = 476)	1.8	1.5	2.3	< .001
Surgical variables				
Augmentation (k = 477)	0.8	0.2	3.1	.69
Condition of the implant site (k = 477)	2.5	1.2	5.4	.02

RCT = root canal–treated.

Table 3 Multivariate Cox Model (Adjusted) Associated with Implant Failure (n = 209 subjects, k = 477 implants)

Exposures	Hazard ratio estimate	95% CI		*P*
Age (per year increase)	1.02	0.99	1.1	.08
Gender (female)	1.2	0.6	2.4	.64
Condition of implant site (delayed)	3.7	1.6	8.3	.002
Coating (no.)	22.1	6.6	74.6	<.001
Total pontic units (per unit increase)	1.8	1.3	2.5	<.001

to selecting immediately loaded implants, primarily increased convenience for the patient, there may be an associated price to pay in terms of a decreased rate of implant survival compared to implants placed and loaded in a more conventional manner.

The second specific aim of this report was to identify factors associated with an increased risk for failure of immediately loaded implants. By using the Cox proportional hazards model to adjust for other covariates, 3 variables associated with an increased risk for failure were found. The first variable, total number of pontics used in the temporary prosthesis ($P < .001$), had a 1.8-fold increased risk for implant failure with each additional pontic added to the restoration. It should be noted here that we did not distinguish, for example, 3 consecutive or serial pontics placed between 2 implants as constituting a prosthesis, as opposed to 5 implants splinted together with 1 pontic between each implant (3 pontics) to constitute a prosthesis. These 2 prostheses might behave differently.

The second variable was status of the implant recipient site at the time of placement (ie, a fresh extraction site or a healed or healing extraction site). Implants placed in a delayed manner were associated with an increased risk for failure (adjusted hazard ratio = 3.7, $P = .002$) compared to implants placed in a fresh extraction site. The third variable was implant coating (ie, coated versus uncoated). Uncoated implants had a 22.1-fold increased risk for failure compared to coated implants ($P \leq .001$). However, the sample size was small for the uncoated implants, and the statistical significance of this might be due to chance.

A previous study reported a 100% success rate for immediately loaded implants placed in healed sites and an 82.4% success rate for immediately loaded

implants placed in fresh extraction sites.[13] This is approximately a 20% risk of failure for immediate loading of single-tooth implants placed in fresh extraction sites.[13] The current study shows that immediate placement of implants decreases the risk of failure for immediately loaded implants. The large sample size of implants placed into fresh extraction sites, 239, compared to 19 implants in the other study, is a possible reason for the difference in results.

The 3 risk factors statistically associated with implant failure (coating, total pontic units, and condition of implant site) may be controlled by the clinician. A clinician can choose to use only coated implants to decrease the risk of failure. The study results suggest that clinicians should minimize the number of pontics in the restoration. In fact, based on these results, one may hypothesize that the ideal situation would be to replace each missing tooth with an implant rather than a pontic. If a tooth is to be extracted before implant placement, the clinician can choose to place the implant in the fresh socket instead of waiting for the socket to heal. This study showed that placement of implants in fresh sockets reduces the risk of implant failure. This may be because there is less bone resorption, so that the bone volume is sufficient to ensure primary stability.[17] Other benefits of immediate placement are that the soft tissue can be maintained and that the implant can be placed in the same position and with the same inclination of the natural tooth it is replacing.[17] Using these recommendations, the clinician can decrease the risk of failure of immediately loaded implants.

CONCLUSIONS

The results of this analysis suggest that the overall 1-year survival of immediately loaded implants is 90.3%, with an associated 95% CI of 86.9% to 93.7%. Timing of implant placement relative to extraction, the use of uncoated implants, and number of pontics used were related with an increased risk of implant failure. The sample size was small for the uncoated implants, and the statistical significance of this might be due to chance. In terms of clinical treatment planning, these factors might be modified to enhance the predictability of implant success and survival in immediately loaded implants.

ACKNOWLEDGMENTS

The authors would like to acknowledge the clinicians and support staff of the Implant Dentistry Centre, Faulkner Hospital, Boston, Massachusetts, for their cooperation in this study and unrestricted access to patient records. They would also like to acknowledge the support of the computing facilities at the Harvard School of Public Health for access to statistical software. This project was supported in part by the Oral and Maxillofacial Surgery Foundation Clinical Investigation Fellowship (SKC), NIH-NIDCR Mid-career Investigator Award – K24 DE000448 (TBD), and Department of Oral and Maxillofacial Surgery Education and Research Fund (ME, SKC, RHY, TBD).

REFERENCES

1. Adell R, Lekholm U, Rockler B. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. J Oral Surg 1981;10:387-416.
2. Aires I, Berger J. Simultaneous immediate placement and immediate loading of implants in the maxilla: A case presentation. J Calif Dent Assoc 2002;30:227–232.
3. Lorenzoni M, Pertl C, Zhang K, Wimmer G, Wegscheider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. Clin Oral Implants Res 2003;14:180–187.
4. Esposito M, Worthington HV, Coulthard P. Interventions for replacing missing teeth: Different times for loading dental implants. Cochrane Database Rev. 2003;(1):CD003878.
5. Hruska A, Borelli P, Bordanaro AC, Marzaduri E, Hruska KL. Immediate loading implants: A clinical report of 1301 implants. J Oral Implantol 2002;28:200–209.
6. Ibanez JC, Jalbout ZN. Immediate loading of Osseotite implants: Two-year results. Implant Dent 2002;11:128–134.
7. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System TiUnite and machined-surface implants in the posterior mandible: A randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003;5(suppl 1):57–63.
8. Schnitman PA, Wohrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997;12:495–503.
9. Yoo RH, Chuang SK, Erakat MS, Weed M, Dodson TB. Changes in crestal bone levels for immediately loaded implants. Int J Oral Maxillofac Implants 2006;21:253–261.
10. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark, P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–210.
11. http://www.bicon.com/tech/t_isf01.html
12. Gapski R, Wang HL, Mascarenhas P, Lang NP. Critical review of immediate implant loading. Clin Oral Implants Res 2003;14:515–527.
13. Chaushu G, Chaushu S, Tzohar A, Dayan D. Immediate loading of single-tooth implants: Immediate versus non-immediate implantation. A clinical report. Int J Oral Maxillofac Implants 2001;16:267–272.
14. Nikellis I, Levi A, Nicolopoulos C. Immediate loading of 190 endosseous dental implants: A prospective observational study of 40 patient treatments with up to 2-year data. Int J Oral Maxillofac Implants 2004;19:116–123.
15. Chuang SK, Tian L, Wei LJ, Dodson TB. Kaplan-Meier analysis of dental implant survival: A strategy for estimating survival with clustered observations. J Dent Res 2001;80:2016–2020.
16. Chuang SK, Wei LJ, Douglass CW, Dodson TB. Risk factors for dental implant failure: A strategy for the analysis of clustered failure-time observations. J Dent Res 2002;81:572–577.
17. Rosenquist B, Grenthe B. Immediate placement of implants into extraction sockets: Implant survival. Int J Oral Maxillofac Implants 1996;11:205–209.